Areawide Management of Codling Moth in Mendocino Orchards: Integrating and maintaining benefits of selective control of secondary pests

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This is the second year of an implementation program in the Mendocino pear district aimed at facilitating and broadening the adoption of codling moth mating disruption. In 1997 we increased the acreage under pheromone confusion by 150, for a total of 550 acres. Organophosphate use for codling moth control was reduced by 80%. Populations of codling moth were reduced by 35 to 65% from the previous year and damage at harvest ranged from 0 to 0.3%. There was a slight increase in leafroller damage; pests of increased concern were various true bugs, primarily boxelder bug. The highest damage due true bugs was close to the river. Mite populations were quite variable and stimulation of mite populations following OP applications did not occur. Bioassays to test for acaricide susceptibility in two spotted mites revealed a 10 fold resistance to abamectin and 3 fold resistance to Vendex in two populations in Mendocino County. In weekly meetings the data was shared and experiences, successes and problems were discussed. Sharing data among all participants has allowed us to build confidence in monitoring fields under mating disruption both for codling moth and secondary orchard insect pest.

Results and Discussion

Objective 1: Implement areawide management of codling moth with pheromone mating disruption in Mendocino County pear orchards.

This year we increased the area under mating disruption by 150 to a total of 550 acres. Isomate-C+ dispensers were applied twice. The first application was made in the last week of March at a rate of 400 dispensers per acre. The second application was made in the first week of June at approximately 900 degree-days for codling moth development. For the second application we modified the protocol and applied the dispenser at 1/2 the rate (200 dispensers/acre) in an effort to reduce cost. Below I describe a post harvest evaluation performed to evaluate if the reduced dispenser rate continued to provide disruption after harvest and thus provided an added benefit by reducing populations in subsequent years.

Weekly monitoring for adult codling moth relied on pheromone traps baited with 10 times the normal rate of pheromone and placed at a density of one trap per 2.5 acres. Extra traps were placed at the borders of the project and near packing sheds and bins in storage. In addition one trap for every 20 acres was baited with a 1 mg codlemone lure. Private consultants monitored with traps baited with 10 mg lures for every 10 acres. All data collected were shared among the participants of the project. Codling moth trap catches were significantly lower in 1997 than those in 1996 for the entire project, (see Fig. 1). This reduction was most evident in the those blocks which had high populations in 1996 (Fig. 2). The average cumulative trap catches were reduced by 35 % over the entire project with reductions of up to 75% in the blocks which had high populations in 1996. We tracked codling moth seasonal trends in flight activity and generation development with the 10X lures. The trap catches were the most reliable tool to determine if supplemental cover sprays were needed. Trap data collected by the PCA's followed the same trend (Fig. 3) and predicted the same "hot spots" as those collected by the project coordinator. These data show that 1 trap each 10 acres would be an appropriate monitoring tool. It would be unrealistic to expect PCAs to set more than 1 trap every 10 acres given the cost in time and materials. Sharing monitoring techniques and data between the project coordinator and PCAs has built confidence in monitoring blocks under pheromone confusion among the private consultants and the growers. This is a key element for growers to continue the program once the project ends.

Organophosphate (OP) use for codling moth control was reduced by 80 %. Of the 550 acres under pheromone confusion, 69% (380 acres) received no cover sprays, 19% (103 acres) received 1 cover spray and 12% (66 acres) received 2 cover sprays (see Map "Organophosphate cover sprays"). We were uncertain of the history of codling moth population on some of the acres added in 1997. Therefore, 54 acres of the recently incorporated 150 acres received a preventive first cover spray, applied at approximately 300 degree-days. A first cover spray was also applied on two blocks of 50 acres each where traps baited with 10X lures exceeded 5 moths/trap/week in two consecutive weeks. A second cover spray, timed for the beginning of the second generation (1100 dd), was applied at three sites where trap counts exceeded 15 moths/trap/week. At these three sites only the areas in which there was a consistent trap catch were sprayed. Two blocks with exposed upwind borders (see Map) received 2 border sprays on the first 6 rows for a total of 10 border acres sprayed. In this second year we exceeded the target of 75% reduction based on other areawide projects and the 66% reduction in our first year.

Program efficacy was determined by fruit evaluations 4 times during the growing season as described in the methods and procedures of the proposal (preceding the second application of pheromone, ground samples after June drop, and at first and second harvest). For monitoring purposes, the project's 550 acres were divided into 36 fifteen-acre sites. The first sample was taken at approximately 900 dd on May 30, June 2-4 to estimate the effects of infestation after the first codling moth generation. One thousand fruit were inspected per site (10 each from top and bottom of 50 trees) and scored for fruit injury from codling moth, leafrollers, lygus, boxelder bug/ stink bug and mealybugs. Five percent of the fruit was cut to look for hidden infestations. The ground sample was taken at 1400 dd on July 1-3. One thousand fruit per block were collected from the ground, cut and evaluated for worms. Bin samples were taken during the first and second harvests at 1000 fruit for every 15 acres.

We detected very low codling moth damage (three sites with 0.1%) in the fruit sampled prior to the second application of pheromone (Table 1). To verify that trap catches accurately reflected the population of codling moth present and to avoid finding ourselves in the situation of not detecting them with the traps but suffering damage at harvest, we periodically inspected fruit for egg laying and early entries or stings. We also evaluated the tops of the trees with an orchard squirrel in early July in those areas where trap catches or prior assessments indicated codling moth or leafroller populations. No codling moth damage was detected when sampling the ground fruit during the June drop or when sampling the tops of the trees with an orchard squirrel (Table 2).

Codling moth damage at harvest was very low (see Map "Codling Moth at Harvest"). Thirty-two of the 36 monitoring sites had no codling moth damage at harvest (Table. 3). Only four blocks had any detectable codling moth damage, ranging from 0.1 to 0.3%. In Farm 2, blocks "99" and 39" experienced 0.2 and 0.3% damage during the second harvest. These two adjacent blocks had a history of codling moth pressure with 8% damage at harvest in 1995 prior to starting the areawide mating disruption project. The high codling moth population prior to starting the project is attributed to documented guthion resistance in this population. In addition these blocks are irrigated with overhead sprinklers. The combination of starting with a high population, which is resistant to guthion and the residue being washed off by the irrigation may have contributed to the higher damage in these blocks. After two years the populations of codling moth in these "hot spot" blocks have decreased substantially (Fig. 2) and we achieved control while reducing the organophosphate (OP) use by 50%.

Two adjacent sites in which codling moth is controlled conventionally with organophosphate were monitored to assess codling moth populations in the area. The Wilson site received three OP cover sprays and the Ford site received two OP sprays. The latter site did not have a history of codling moth damage in the previous year and it appears that the reduced number of sprays resulted in a 1.2% infestation at harvest. This indicates that there is codling moth pressure in the area of the project and that mating disruption alone protected the 69% of the acreage that received no cover sprays.

After the first and second harvests all fruit which had fallen to the ground was removed from the orchards to reduce the overwintering population. Since we reduced the second application dispenser rate this year by half (200 dispensers/acre), we undertook a post-harvest evaluation to assess the percent fruit infestation after harvest. Nine sites were selected from inside the project and two adjacent sites managed conventionally were selected for comparison. The number of fruit remaining on the tree was estimated by counting all the fruit of 10 trees per site. Percent infestation was assessed three weeks after harvest by randomly collecting 500 fruits per site, cutting them open and examining them for presence of codling moth damage. The results are presented in table 4. Post-harvest infestations did not increase at two sites in the project ("99" and Big Orchard) as compared to harvest infestation levels. They increased by 3X at the "39" block and by 12 X at Farm 3 Middle block. Infestation in both the conventional orchards increased by 10X. In the spring we will compare post-harvest populations to spring trap catches to determine if the dispensers are providing protection after harvest. To determine the longevity of the dispensers remaining in field we continue to weight 50 dispensers weekly to monitor for pheromone release through weight loss.

Low levels of oblique banded leafroller infestation were detected in 15 sites of the 36 sites monitored (see Map "Leafroller at Harvest"). In 14 sites infestations ranged between 0.1 to 0.4% and the remaining site had 1.1% (Table 3). This is an increase from last year where a single 10 acre block had 0.005% infestation at harvest. Low level leafroller damage was detected early in the season during the early June evaluation (Table 1) and the tree top evaluation (Table 2) but no control measures were considered necessary. There have been reports of leafroller problems from the Northwest Areawide projects, so we must watch carefully in the coming year. We also saw an increase in boxelder or stink bug damage (Table 3 and Map "True Bugs at Harvest"). We suspect that the damage is due primarily to boxelder bug because during spring monitoring we observed boxelder bug eggs, and later nymphs. The largest damage was observed in the rows adjacent to the Russian River (see Table 3, the blocks of each farm are listed in order by distance from the river, and Map). Mealybug was observed at the same site as last year (Farm 4) and in the same percentage.

Objective 2: Demonstrate and maintain enhanced selective management of the secondary pest, spider mites.

Sub-objective 2a: To evaluate shifts in spider mite and predatory mites populations under areawide mating disruption for codling moth relative to the potential for effective biological control of spider mites.

The protocol was modified to include replications within each mating disruption orchard site. The four treatments were replicated three times at each of the three grower sites, for a total of 36 plots. Originally we had proposed to replicate the four treatments between the grower sites for a total of 12 plots. We felt that this increased replication was warranted given the high variability in mite populations within a site. Treatments remained as proposed with the exception of the fourth treatment. Due to mite damage the experiment had to be terminated early, therefore, the fourth treatment received 3 OP applications instead of 4. The treatments were then: no organophosphates, 1 application per season, 2 applications per season and 3 applications per season. No acaricide was placed until the end of the experiment. Due to mite damage, two of the sites were terminated in the last week of June and, due to high psylla populations, a third site was terminated also in the last week of June. In the two sites which were terminated due to mite damage, the damage was evaluated on a rating system. Ten trees per plot were rated on a scale of 0 to 3, where 0 was assigned to trees with no visible damage, 1 to trees with one branch affected, 2 to trees with more than one branch in the same scaffold affected and 3 to trees where two or more scaffolds were affected.

Mites were sampled on a bi-weekly basis as proposed. Data from the last date sampled at the end of June are presented in Table 5 along with the damage rating for two orchard sites. There was no significant difference due to treatment in the number of mites nor in mite damage. Predatory mites were found at very low numbers. Stimulation of mite populations following OP applications does not always occur. Mite damage varies greatly from year to year and from site to site. Given that at one orchard site populations remained low despite OP applications demonstrated that acaricides are not always needed and that monitoring is very important to avoid the overuse of acaricides. One of the benefits of a mating disruption program is that it decreases the chances of disrupting the predator complex and thus lowering the chances that mites may flare up. Better understanding of threshold levels for mite outbreaks under pheromone confusion is needed.

Sub-objective 2b: Develop resistance management strategy for spider mites so as to maintain selective options

Historically, spider mites have proven remarkably capable of detoxifying a broad array of pesticides in a relatively short period of time. In the mid-late 1980s, problems with resistance to the organotin compounds resulted in a wider array of pesticide mixtures that included compounds like Carzol (formetanate hydrochloride) which are fairly disruption to overall system stability. Use of broad spectrum insecticides like Carzol may result in disruption of ecosystem balance through predator elimination which in turn may increase overall pesticide use needs.

The introduction of abamectin (Agrimek) for management of both spider mites and pear psylla provided a selective and effective alternative to these pesticide mixtures. In addition, an ovicidal acaricide, Apollo (chlofentezine), has also become available as an alternative selective material. However, the long-term use of both of these products has not been placed into an effective resistance management context so as to preserve their longevity and usefulness to California agriculture.

The first step in developing such a program is to determine initial levels of resistance and ultimately patterns of cross resistance such that programs focusing on rotational sequences of acaricides might be developed and optimized.

Colony sources. and maintenance: Two-spotted spider mites (*Tetranychus urticae*) were collected from pear orchards during the 1997 growing season. Three colonies were collected from pear orchards in Mendocino County, CA during June - August, 1997, and are referred to as Ukiah, Mendocino 1 and Mendocino 2 colonies. Two colonies collected from pear ranches in the Sacramento River delta region near Courtland, CA during August and October, 1997, are referred to as E1 and Tower colonies. While only 3 locations were proposed originally, 2 additional sites were collected for inter-regional comparison. Colonies were collected from 2 distinctly different regions that have historically exhibited different patterns of resistance. More acute problems with resistance in spider mites were first found in Mendocino and Lake counties which in addition in some years have more acute problems with pear psylla. Abamectin has proven effective against both pear psylla and spider mites, but the effective rates differ. As such, the higher rates of abamectin required for effective suppression of pear psylla also increases the selection pressure for resistance to spider mites.

Field collected mites were transferred to pinto bean plants (Phaseolus vulgaris) and reared in cages in a greenhouse until populations reached adequate numbers for testing. Beans were grown in plastic bags filled with vermiculite. The mite colonies were reared at green house temperatures of 65-90^{o}F and a 16:8 (light:dark) photoperiod. Colonies were collected in the fall of 1997, but the final bioassays were not completed until the spring of 1998. As such, the colonies have had approximately 6 months to decline in resistance levels due to any potential fitness costs that might be associated with acaricide resistance.

Bioassay procedures. Leaf disks 2 cm diameter were cut and placed bottom side up on wet cotton placed in 1 oz. plastic cups (Solo ®), a single disk per cup. A minimum of 20 adult female mites were then transferred by fine camel hair brush from bean leaves to each leaf disk. Five replicates (minimum 100 mites) were transferred for each dose of a given bioassay. In the original proposal, abamectin, Vendex, and Kelthane were proposed as materials to be tested. Abamectin is the mainstay of mite management program in pears. However, limited use of Kelthane as an effective acaricide in pears makes this a less acceptable candidate. A third acaricide (e.g. Apollo) will be substituted for Kelthane for use in pears.

Dose response to abamectin (Agri-Mek 0.15EC) was evaluated over a six concentration series plus a water only control. The following dilution were made in water: 1.0, 0.3, 0.1, 0.03, 0.01, and 0.001 mg AI/liter. Solutions were applied by Potter Spray Tower (see below).

Dose response to hexakis (Vendex 50W) was evaluated over a five concentration series plus a water only control. The following dilutions were made in water: 300, 100, 30, 10, 3 mg AI/liter. The E1 and Mendocino 2 colonies were tested with a maximum dose of 100 mg AI/liter.

A Potter Spray Tower was used to apply 2 ml of solution at 15 psi with a 10 second settle time using the small spray nozzle. Up to three disks would be treated with a single spray; the disks with each spray would represent the two or three colonies being tested on that day. Disks were then held at 24°C for 72 hours. Mortality was evaluated by prodding each mite with a camel hair brush to determine ability to walk. Mites were classified as alive (able to move one or more body lengths), dead (no movement), moribund (able to move but not walk more than a body length), or runoff (found in water or cotton). Dose response data were analyzed by POLO-PC (LeOra Software, Berkeley, CA).Dose response lines were obtained from each colony for abamectin (Agri-Mek 0.15EC) and hexakis (Vendex 50W).

Results

The results of the bioassays for abamectin (Agri-mek) are shown in Table 6 and Figure 4. The data are given as both the slopes of the probit lines as well as the individual LC_{10}, LC_{50}, and LC_{90} values. In addition, the results of the resistance ratios are expressed as a ratio of the most susceptible site, the E1 colony. Significance levels of these resistance ratios were determined by lethal ratio testing as described by Priestler and Robertson.

Abamectin resistance levels differed significantly between the 5 sites with low resistance levels noted in both sites in the Sacramento Delta and one site in Ukiah, CA in the Mendocino Valley. However, 2 additional sites in Mendocino, CA exhibited significant increases in resistance levels. Contrasts of resistance levels with the E1 colony showed that the Tower and Ukiah sites had statistically significant elevation in resistance levels at 1.7 and 4.0 fold resistance levels. However, the orchards listed as Mendocino 1 and 2 exhibited statistically higher resistance levels to abamectin as shown by the 10-11 fold resistance ratios for the LC_{50}s.

Overall, a similar pattern existed for Vendex with the most susceptible site found in the E1 colony from the Sacramento delta (Table 7 and Figure 5). Resistance levels were significantly elevated for the 2 plots listed as Mendocino 1 and 2, but the resistance ratios were lower than observed for abamectin. The Ukiah colony did not have any significant resistance levels to Vendex.

Currently, additional studies are underway for Apollo, which is ovicidal in nature. Additional studies are planned for a new acaricide, pyrimite (pyridaben) which has a different mode of action.

Implications

The data are the first indications of a potentially serious problem with managing spider mites using our existing chemistries. Fortunately, newer chemistries are coming on line which may not exhibit cross resistance. One of these compounds was not available at the start of this proposal. As such, an aggressive effort will need to be launched this spring using our existing 5 colonies to determine which compound if any offers a reasonable alternative material which will not exhibit cross resistance.

Interestingly, the pattern with spider mite resistance between the 2 pear growing regions is somewhat reminiscent of previous patterns with spider mite resistance. In the mid-late 1980s, the loss of the organotin compounds as effective spider mite materials was especially acute in the more coastal counties of Lake and Mendocino. Over the past 10 years, several arguments have been put forward to attempt to explain the discrepancy between Sacramento and the North coast counties. The evolution of resistance in spider mites in California pears was originally studies and discussed in the 1980s and early 90s by J. Grannett's laboratory at UC Davis.

Traditionally, problems with pear psylla have appeared more acute in the North coast counties which in some cases has resulted in more intensive treatments for psylla. The problem is that the use of abamectin for psylla control may require application rates of 16-20 oz per acre rather than the lower rates used for spider mite control. As such, the pear psylla program inadvertently increases the selection pressure for spider mite resistance.

The second hypothesis put forward to explain the difference has been the distribution of cropping systems within each region. In the North Coast counties, the plantings of pears is more uniform as a percentage of the acreage compared the more mixed cropping systems in the Sacramento Delta. Whereas other crops such as grapes also support spider mites in the North coast counties, the level of spider mite problems in these vineyards is relatively small compared to either pears or grapes grown in the Central Valley. Therefore, you might predict that the relative contribution of grapes to the overall spider mite gene pool in pears might be relatively limited.

In contrast, a more diverse cropping systems that may or may not harbor high mite population (e.g. apples, almonds, alfalfa,..) in the Sacramento region may contribute a greater proportion to the overall gene pool for the area. The mixing across crops has been speculated to reduce overall selection pressure in the delta pears.

However, neither of these hypotheses has been directly tested in pears for abamectin. The first step of the post-hoc analyses will have to include a detailing of the historical spray records for the orchards both exhibiting or not-exhibiting resistance to both Abamectin and Vendex.

Plans for rotational sequences of acaricides still hinges on final testing for 2 additional acaricides not originally targeted by the study. However, because of newer registrations, these studies will prove much more useful than the originally proposed material, kelthane. As such, the detection of very low levels of resistance in the Sacramento delta in particular and the relatively low resistance levels in Mendocino counties, combined with 2 compounds with very different modes of action may represent an excellent opportunity to actively manage resistance in the field.

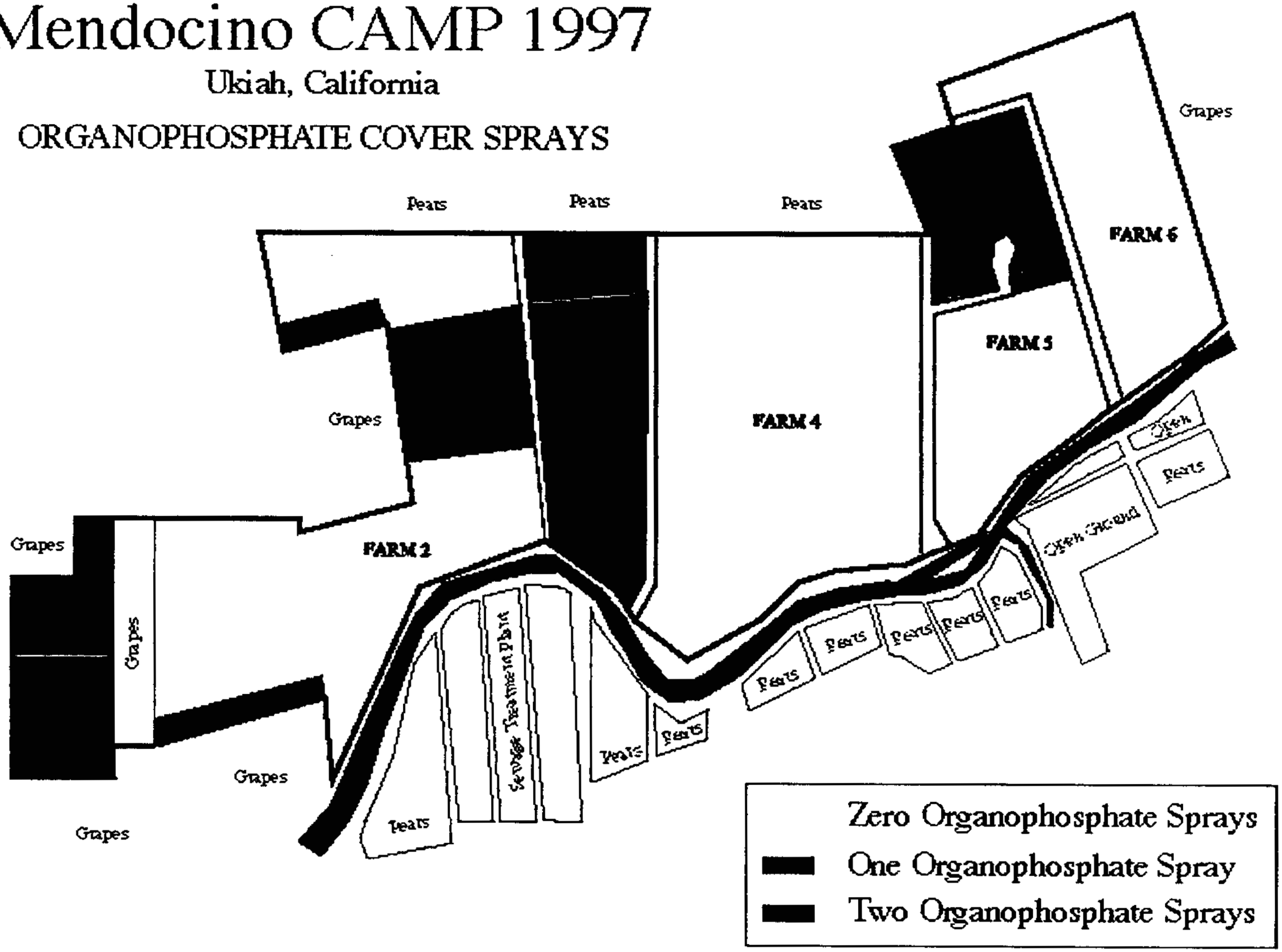
Sub-objective 2c: To develop extension tools and information and information transfer for implementing spider mite management protocols in areawide programs

A weekly report with trap catches and secondary pest monitoring was shared with project growers and PCAs. One-hour weekly meetings were conducted every Thursday with PCAs working in pears in Mendocino County and representatives of the Agricultural Commissioner's Office. At these meetings, the weekly monitoring report was discussed and data collected by the project coordinator and the PCAs were compared. Experiences, successes and problems were discussed. A tour of the project was conducted for representatives of the pear industry, pear growers, researchers and government officials on May 27th. A half day seminar is scheduled for October 29th in Ukiah to present a progress report to Mendocino Pear growers.

Mendocino CAMP 1997

Ukiah, California

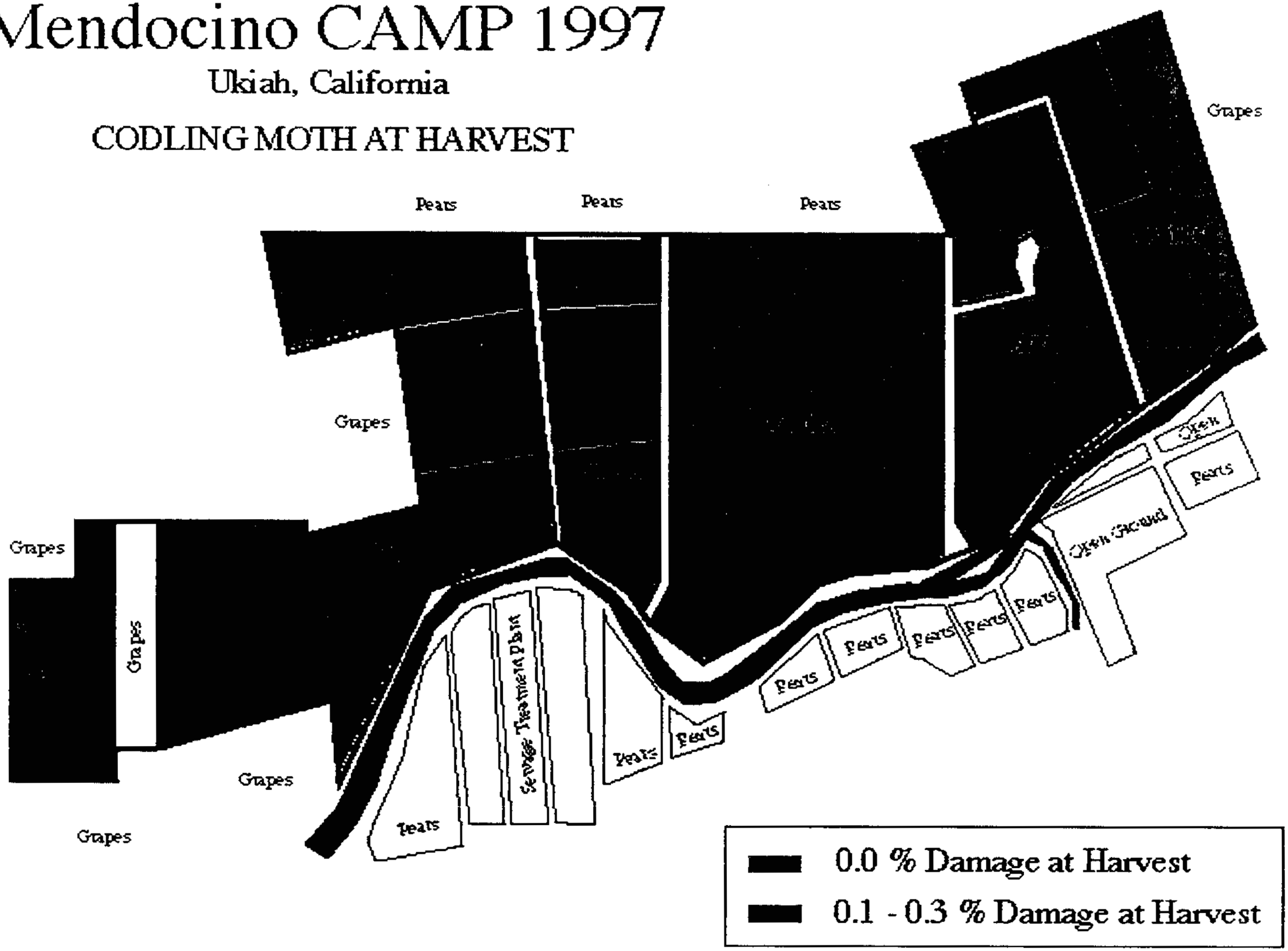
ORGANOPHOSPHATE COVER SPRAYS



Mendocino CAMP 1997

Ukiah, California

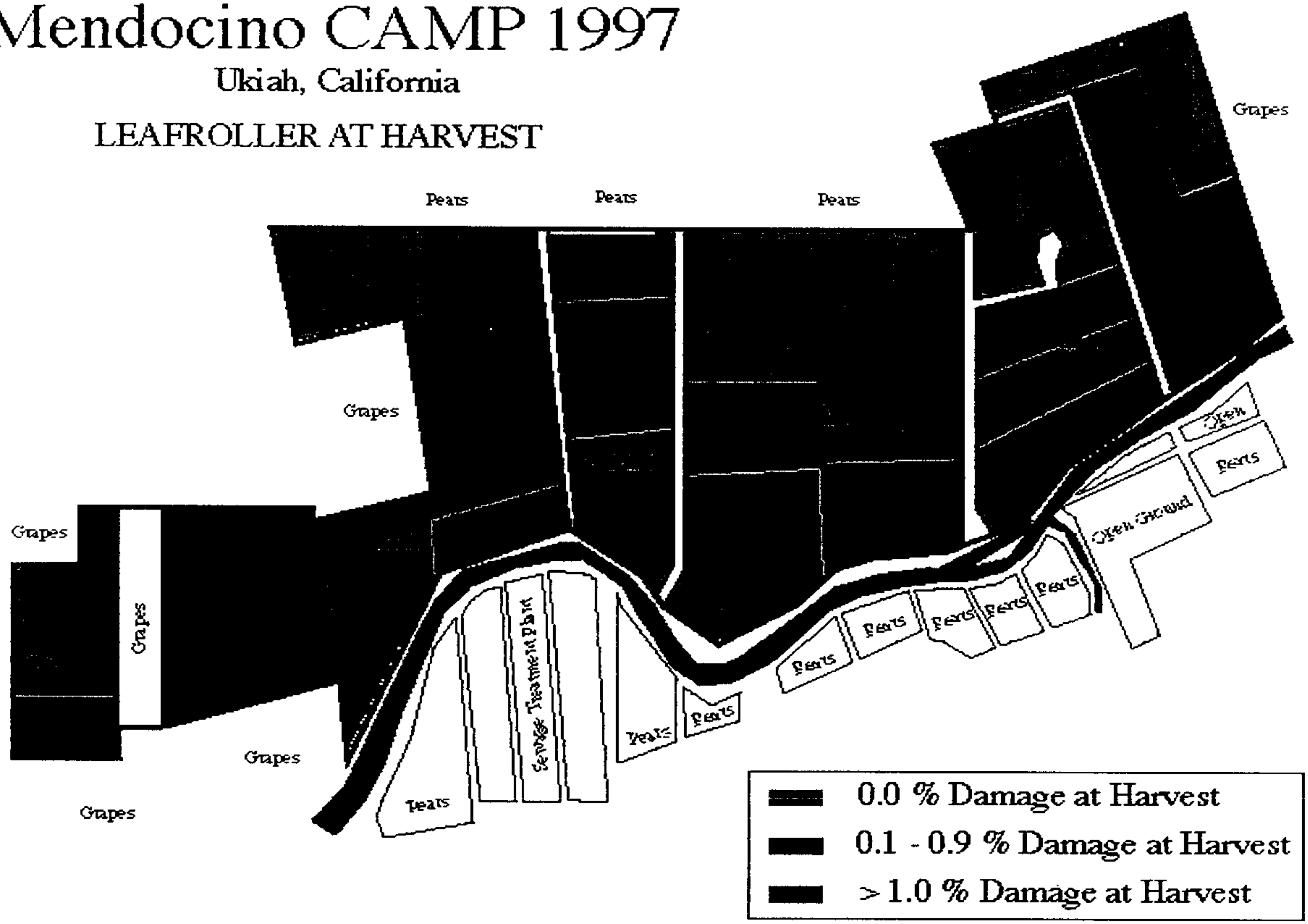
CODLING MOTH AT HARVEST



Mendocino CAMP 1997

Ukiah, California

LEAFROLLER AT HARVEST



Mendocino CAMP 1997

Ukiah, California

TRUE BUGS AT HARVEST

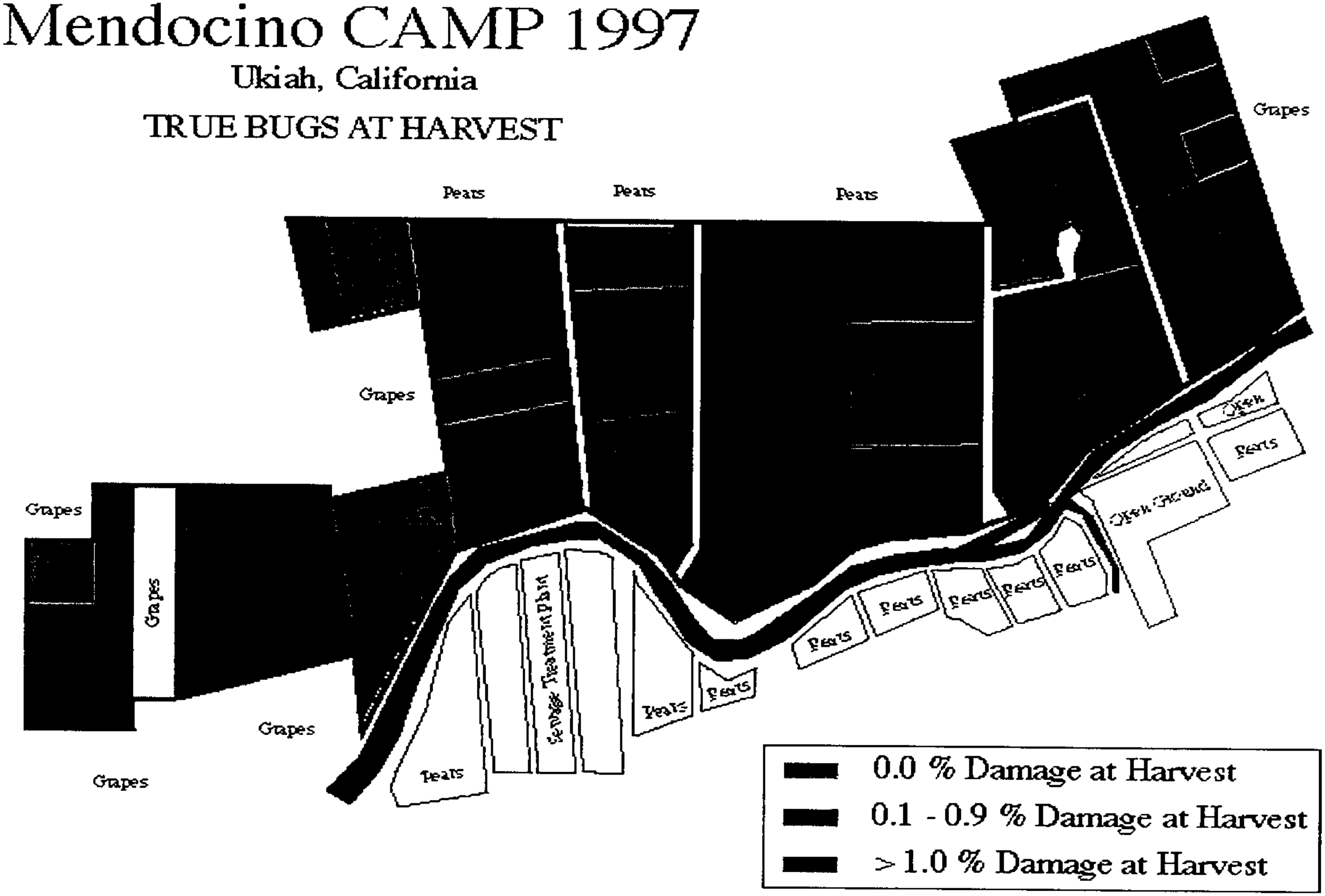


Fig 1. Weekly trap catches for the Mendocino Areawide Project during 1996 and 1997

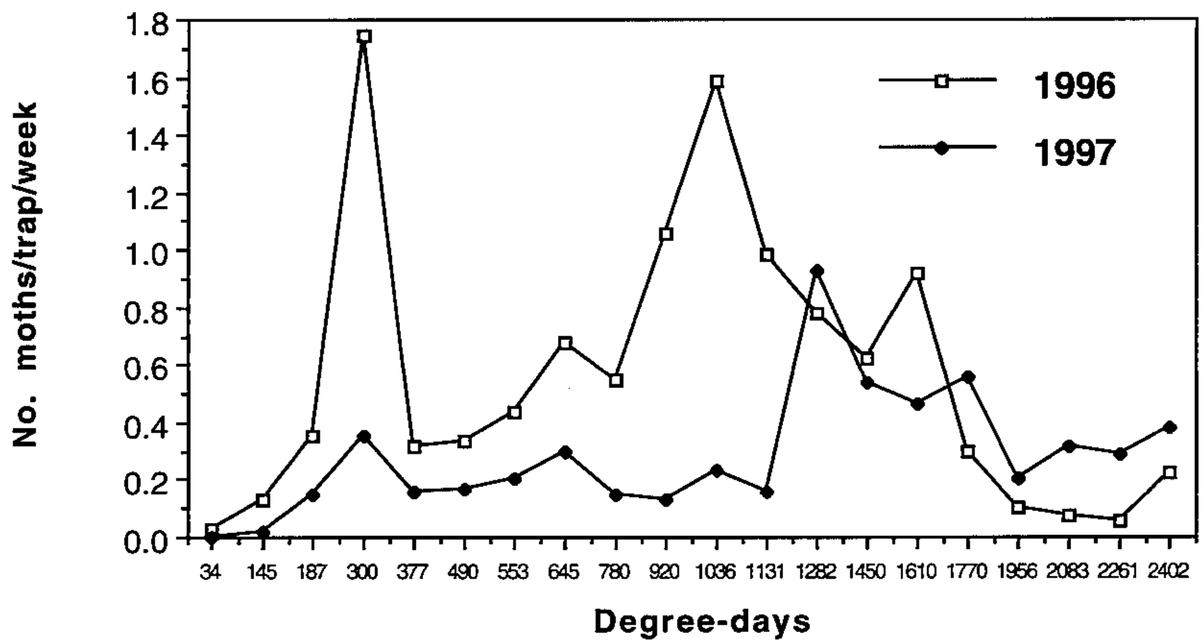


Fig 2. Weekly trap catches for Block "39" in Farm 2 during 1996 and 1997

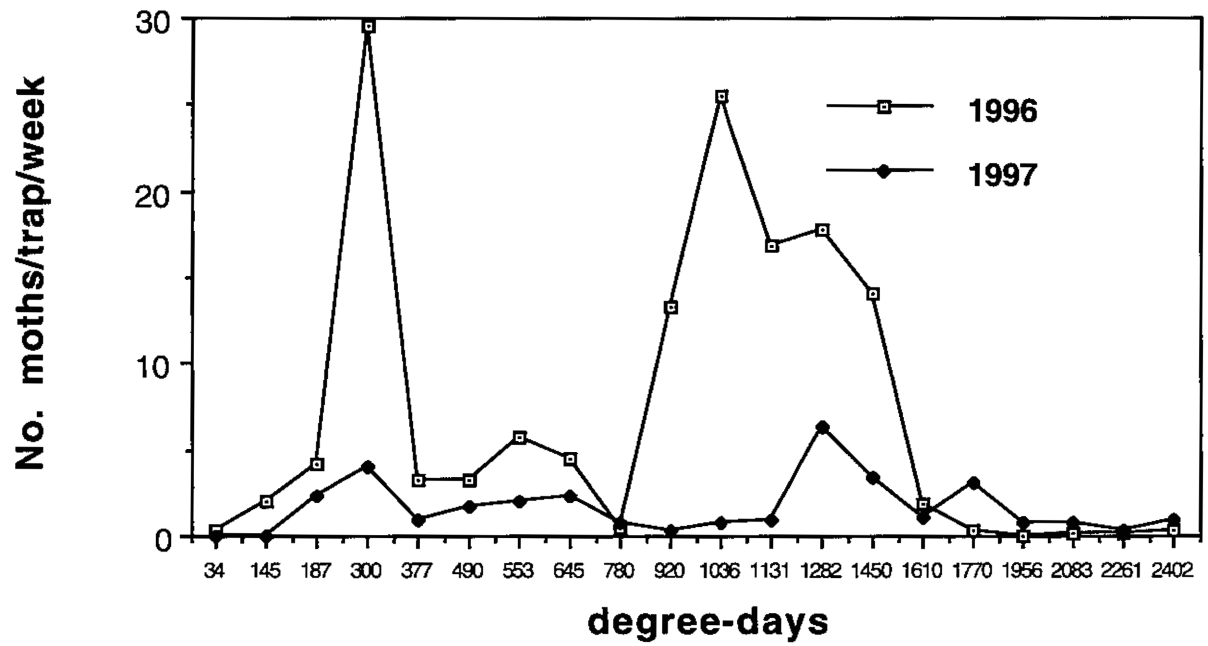
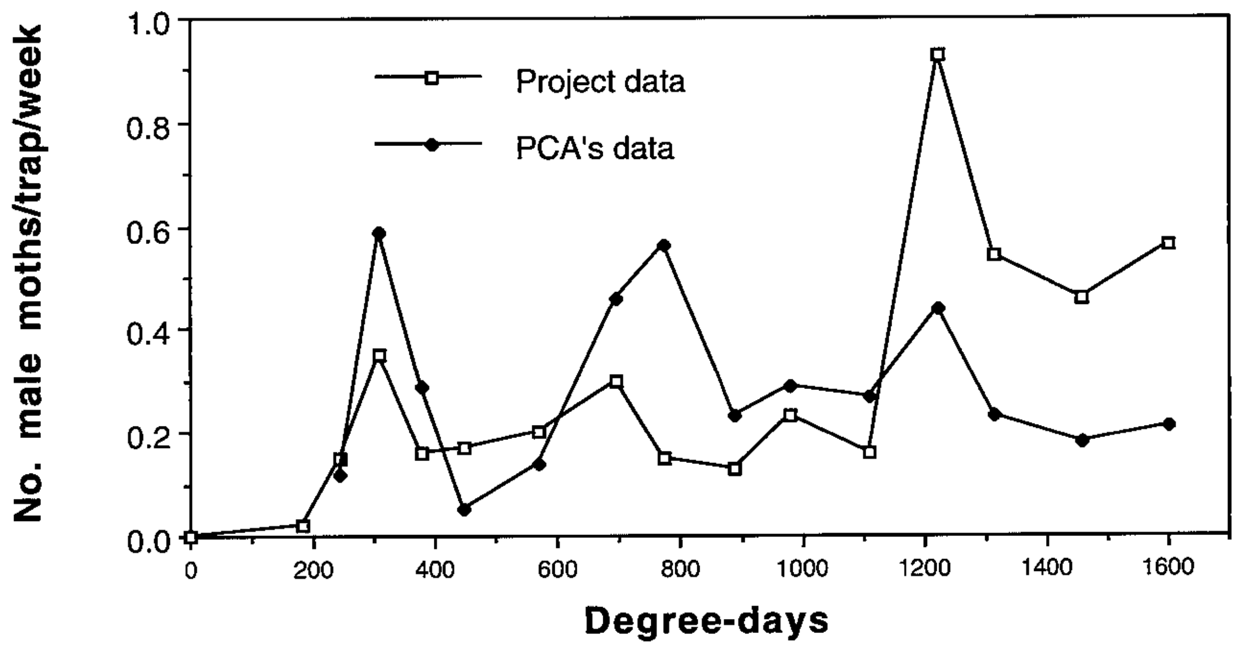


Fig. 3. Comparison of weekly trap catches between PCA'S and Project Coordinator data



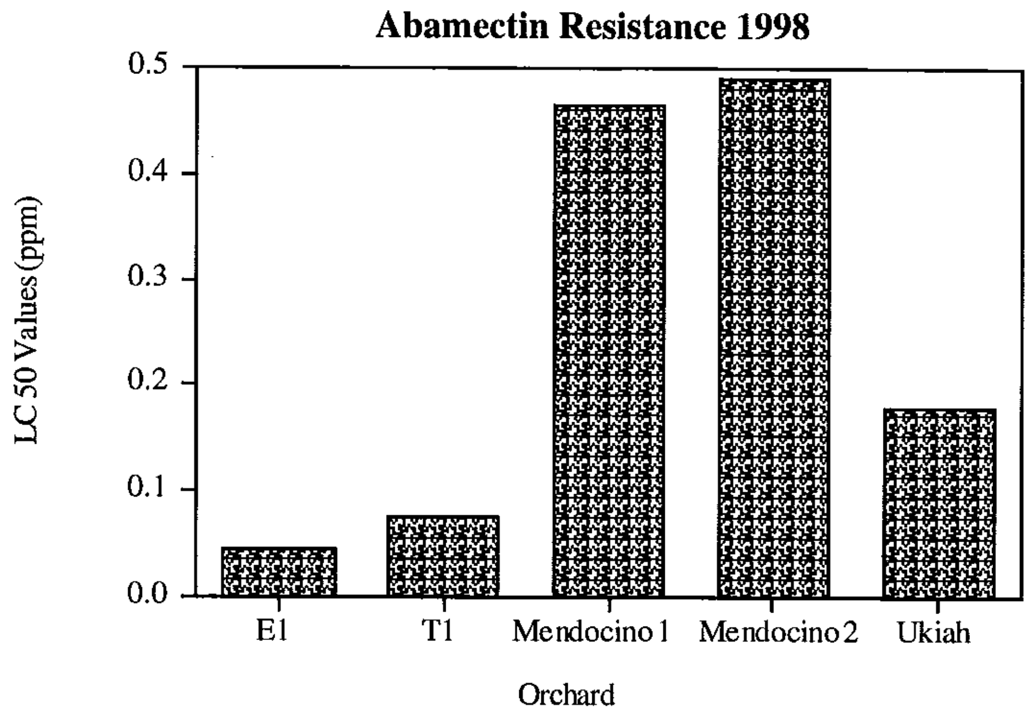


Figure 4. LC 50 values for abamectin resistance in 5 orchards (E1 and T1 - Sacramento County)

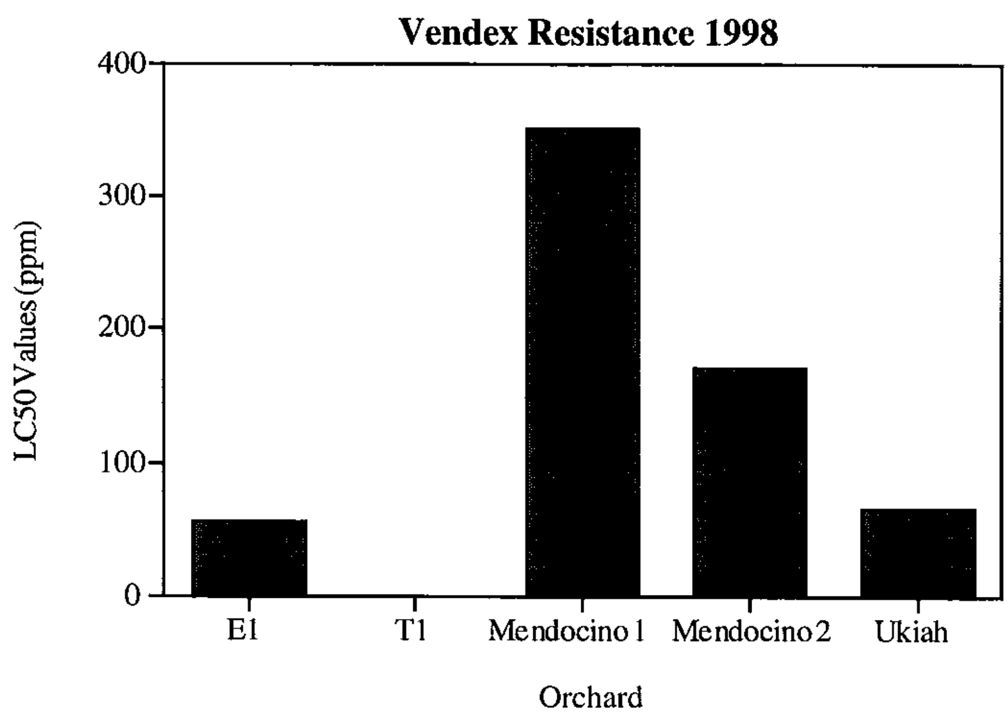


Figure 5. LC 50 values for Vendex resistance in 5 orchards (E1 and T1 - Sacramento County)

Table 1. Codling moth, leafroller, lygus and boxelder bug/stink bug percent damage evaluated during the first week of June at the end of the first codling moth generation.

	% Damage in early June			
	Codling Moth	Leafroller	Lygus	Boxelder/ Stink bug
Farm 1	0.0	0.0	0.0	1.2
Farm 2				
Starkcrimson	0.0	0.0	0.0	0.2
Bosc	0.0	0.0	0.0	0.0
"99"	0.0	0.0	0.3	0.3
"39"	0.1	0.1	0.6	0.2
Red Sensation	0.0	0.0	0.6	0.1
12x20	0.0	0.0	0.1	0.1
Comice	0.0	0.0	0.0	0.1
Stickney	0.0	0.1	0.0	0.9
Farm 3	0.0	0.1	0.2	0.7
Farm 4	0.0	0.0	0.0	0.9
Farm 5				
West Block				
River	0.0	0.0	0.0	6.9
Camp	0.0	0.2	0.5	1.2
East	0.0	0.1	0.5	0.7
East Block	0.1	0.0	0.4	0.8
Farm 6				
River	0.1	0.0	0.4	3.8
Comice	0.0	0.0	0.0	0.1
Big orchard	0.0	0.0	0.0	1.4
Scattered	0.0	0.0	1.5	0.0
Bosc	0.0	0.0	0.1	0.3
Small Comice	0.0	0.0	0.0	0.1

Table 2 - Tree top fruit assessment performed with an orchard squirrel in early July

	% Damage in early June			
	Codling Moth	Leafroller	Lygus	Boxelder/ Stink bug
Farm 2				
"39"	0.0	0.0	0.8	0.8
Farm 3				
Middle	0.0	1.7	0.0	0.4
Farm 5				
West Block				
East	0.0	0.0	0.4	0.0
East Block	0.0	0.0	0.4	0.0
Farm 6				
River	0.0	0.1	0.0	1.5
Big orchard	0.0	0.0	0.0	1.4
Scattered	0.0	0.1	2.5	0.8

Table 3 - Codling moth, leafroller, lygus, boxelder bug/stink bug and mealybug damage assessment during the first and second harvest

		% Damage at Harvest									
		Codling Moth		Leafroller		Lygus		Boxelder/ Stink bug		Mealybug	
Farm	Block	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1	Reds - West	0.0	0.0	0.2	0.2	0.2	0.2	1.0	0.9	0.0	0.0
	Green	0.0	0.0	0.0	0.0	0.4	0.4	0.1	0.3	0.0	0.0
	Reds - East	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	Starkcrimson	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.1	0.0	0.0
	Bosc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0
	"99"	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	"39"	0.0	0.3	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0
	Red Sensation	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0
	12x20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	House	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3
	Comice	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Stickney North	0.0	0.0	0.1	0.1	0.0	0.1	0.1	0.3	0.0	0.1
	Stickney South	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.2	0.0	0.1
3	West (River)	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	0.0	0.0
	Middle	0.0	0.1	0.7	1.1	0.0	0.1	0.2	0.3	0.0	0.0
	East	0.0	0.0	0.4	0.0	0.3	0.0	0.9	0.0	0.0	0.0
	5 acre	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0.0	0.0
4	North block										
	West (River)	0.0	0.0	0.3	0.0	0.3	0.0	0.5	0.2	0.0	0.0
	Middle West	0.0	0.0	0.0	0.2	0.4	0.1	0.9	0.5	0.1	0.8
	Middle East	0.0	0.0	0.0	0.0	0.1	0.1	0.6	0.1	0.3	0.8
	East (Road)	0.0	0.0	0.0	0.0	0.3	0.2	0.3	0.6	0.0	0.0
	South block										
	West (River)	0.0	0.0	0.3	0.2	0.0	0.2	0.9	0.5	0.0	0.2
	Middle West	0.0	0.0	0.3	0.0	0.0	0.1	0.0	0.0	0.0	0.0
	East (Road)	0.0	0.0	0.0	0.0	0.3	0.0	0.9	0.1	0.0	0.1
	Wedge**	0.0		0.0		1.5		1.5		0.0	
5	West Block										
	River	0.0	0.0	0.3	0.2	0.2	0.1	2.2	1.7	0.0	0.0
	Camp	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.5	0.0	0.0
	East	0.0	0.0	0.1	0.1	0.3	0.1	0.5	0.1	0.0	0.3
	East Block	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	River*	0.0		0.3		0.1		1.4		0.0	
	Comice*	0.0		0.2		0.0		1.1		0.0	
	Long Strip*	0.0		0.0		0.0		0.0		0.0	
	Big orchard*	0.1		0.1		0.5		0.4		0.0	
	Scattered*	0.1		0.0		0.6		0.4		0.0	
	Bosc*	0.0		0.0		0.0		0.0		0.0	
	Small Comice*	0.0		0.0		0.0		0.4		0.0	
Conventional sites											
	Wilson	0.0	0.2		0.0		0.0		0.0		0.0
	Ford***	0.6	1.2		0.0		0.0		0.0		0.0

* Only harvested once

** Second harvest was not sampled

*** First harvest was only sampled for codling moth damage

Table 4 - Post harvest codling moth percent infestation and assessment of number of fruit per acre left on tree three weeks after harvest.

	% CM infested fruit at harvest	Mean # rat tails/tree	Mean # green fruit/ tree	Trees/ acre	Average # fruit/acre	% CM infested fruit post-harvest
Farm 1	0.0	9.4 ± 3.8	25.4 ± 14.5	108	3,758	0.0
Farm 2						
"99"	0.2	4.4 ± 2.4	11.2 ± 8.1	218	3,401	0.0
"39"	0.3	6.8 ± 1.6	39.4 ± 21.0	108	4,990	1.0
Stickney	0.0	5.9 ± 3.2	16.9 ± 10.6	108	2,462	0.0
Farm 3						
Middle	0.1	9.8 ± 6.1	48.5 ± 24.2	108	6,296	1.2
Farm 4	0.0	5.5 ± 4.4	21.9 ± 19.0	218	5,973	0.0
Farm 5	0.0	21.2 ±10.4	21.7 ± 6.9	108	4,633	0.0
Farm 6						
River	0.0		266.8 ± 89.7	108	28,814	0.0
Big Orchard	0.1	12.6 ±5.1	35.5 ± 30.1	218	10,486	0.0
Conventional Orchards						
Wilson	0.2					2.2
Ford	1.2					13.8

Table 5 - A) Mean number of mites per leaf sampled during the last week of June at three orchard sites and B) mite damage rating at two orchard sites.

	Mean # mites/leaf			
A)	Control	1 Spray	2 Sprays	3 Sprays
Orchard A	0.54 ± 0.75	0.28 ± 0.46	0.11 ± 0.16	0.32 ± 0.45
Orchard B	0.43 ± 0.49	0.30 ± 0.14	0.54 ± 0.75	0.51 ± 0.50
Orchard C	0.01 ± 0.01	0.03 ± 0.05	0.02 ± 0.02	0.03 ± 0.02
B)	Damage rating			
Orchard A	0.50 ± 0.53	0.47 ± 0.72	0.77 ± 0.72	0.64 ± 0.29
Orchard B	0.23 ± 0.23	0.60 ± 0.27	0.77 ± 0.57	0.63 ± 0.21

Table 6. Comparison of dose response lines for two-spotted mite populations treated with Agri-mek 0.15EC.

Population	slope (s.e.)	LC10 (95% c.i.)	LC50 (95% c.i.)	LC90 (95% c.i.)	RR LC10 (95% c.i.)	RR LC50 (95% c.i.)	RR LC90 (95% c.i.)
E1	5.068 (0.638)	0.025 (0.018-0.030)	0.045 (0.038-0.052)	0.080 (0.067-0.103)	- - -	- - -	- - -
T1	3.369 (0.792)	0.032 (0.001-0.058)	0.076 (0.022-0.105)	0.182 (0.136-0.462)	1.27 (0.62-2.61)	1.71 * (1.20-2.42)	2.29 * (1.65-3.17)
Mendocino 1	3.594 (0.617)	0.204 (0.064-0.312)	0.464 (0.299-0.593)	1.054 (0.801-1.967)	8.21 * (5.11-13.18)	10.42 * (8.15-13.33)	13.23 * (9.66-18.12)
Mendocino 2	5.230 (0.744)	0.279 (0.110-0.406)	0.491 (0.306-0.662)	0.864 (0.641-1.433)	11.24 * (7.81-16.16)	11.04 * (8.71-13.98)	10.84 * (8.26-14.23)
Ukiah	2.900 (0.735)	0.064 (0.001-0.129)	0.178 (0.042-0.253)	0.492 (0.352-1.717)	2.59 * (1.10-6.09)	3.99 * (2.70-5.91)	6.17 * (4.20-9.05)

* Significant RR (resistance ratio) when compared to dose response line of the most susceptible colony in the data set.

Table 7. Comparison of dose response lines for two-spotted mite populations treated with Vendex 50W.

Population	slope (s.e.)	LC10 (95% c.i.)	LC50 (95% c.i.)	LC90 (95% c.i.)	RR LC10 (95% c.i.)	RR LC50 (95% c.i.)	RR LC90 (95% c.i.)
E1	1.587 (0.375)	8.8 (0.450-19.1)	56.5 (33.1-99.8)	362.6 (163.3-7751.9)	- - -	- - -	- - -
Mendocino 1	1.384 (0.323)	41.7 (6.6-78.1)	351.4 (212.5-1161.1)	2964.7 (978.4-121141.4)	4.74 * (1.44-15.65)	6.22 * (3.29-11.78)	8.17 * (1.48-45.05)
Mendocino 2	0.788 (0.156)	4.0 (0.278-10.3)	170.8 (71.8-1761.2)	7226.9 (958.9-5787276.6)	0.46 (0.12-1.75)	3.02 * (1.20-7.62)	19.88 * (1.77-223.3)
Ukiah	1.217 (0.178)	5.8 (0.491-15.2)	65.9 (31.6-135.7)	743.9 (287.2-8548.3)	0.66 (0.19-2.28)	1.17 (0.69-1.94)	2.05 (0.59-7.13)

* Significant RR (resistance ratio) when compared to dose response line of the most susceptible colony in the data set.